Colombia Forestry Development Program

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Technical Assessment of the Laboratorio de Productos Forestales (LPF) at the National University of Colombia in Medellin

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Submitted by:
Chemonics International Inc.

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ACRONYMS

ALSC	American lumber standards committee
ASTM	American Society for Testing & Materials
ASTM D	ASTM Designation
LPF	Laboratorío de Productos Forestales
LVdt	Linear variable displacment transducer
mc	moisture content
MOE	modulus of elasticity
MOR	modulus of rupture
CFDP	Colombia forestry Development plan
PR	proving ring
RRA	renewable resource associates
SG	specific gravity
US	united states
WAS	Wood Advisory Services, Inc.
°c	Degrees clecius
cm	centimeter
FT	Feet
in	inches
kg	kilogram
mm	millimeter
min	minute
n	newton
%	percent
1b	pound
1bf	pound-force

EXECUTIVE SUMMARY

A representative from Wood Advisory Services, Inc. traveled to Medellín, Columbia to perform a technical assessment of the Laboratorio de Productos Forestals. All of the individuals who participated in the technical assessment were a pleasure to work with and demonstrated both enthusiasm and professionalism. I look forward to working with them in the future. The technical assessment was conducted very efficiently with full cooperation from everyone involved. The LPF is kept in a clean and orderly condition and there is plenty of storage available for the lumber. The equipment currently available at the LPF is certainly adequate to conduct a full in-grade testing program that would be acceptable according to the American Lumber Standards, however, modifications are recommended to improve the efficiency of the equipment and personnel so that an in-grade program could be completed in a timely manner.

SECTION I

Scope of Work

A representative from Wood Advisory Services, Inc. (WAS) traveled to the Laboratorio de Productos Forestales (LPF) in Medellín, Columbia. The purpose of the trip was to conduct a technical assessment of the LPF and provide recommendations regarding the performance of ASTM test standard D 4761, AStandard Test Methods for Mechanical Properties of Lumber and Wood-Based Structural Material.

The detailed scope of work for WAS, Inc. presented to Mr. Alfonso Uribe of Chemonics International, Inc. located In Medellín on May 16, 2004 from Mr. Lon Sibert of RRA was as follows:

1. Review all testing equipment and accessories related to the structural testing of lumber at the LPF, and observe its functioning during actual testing of lumber of three different sizes. Make recommendations relative to equipment modifications and/or the purchasing of new equipment to assure that the proposed lumber testing can be performed without any questions of reliability of the data, and that test results would be acceptable to the American Lumber Standard Committee.

2. Review machine calibration techniques and equipment (related to all applicable machines). Make recommendations relative to modifications and/or purchase of new equipment to ensure that the calibration of the machines would be acceptable to the American Lumber Standard Committee.

3. Review and perform if possible (with the available equipment and the allotted time) the correct application of all applicable ASTM procedures and protocol.

4. Clarify all applicable procedures. Make recommendations relative to the collection of data and the use of appropriate forms and systems to facilitate the eventual analysis of the data by WAS, Inc.

5. Observe existing lumber storage facilities and space requirements for the storage of pieces of lumber after testing.

6. Evaluate the performance and capabilities of the CFDP agents or personnel selected to carry out the tasks of lumber testing and data registration.

7. Assess the testing process, data collection requirements, formats, reports, and all other matters involved with test results, based on ALSC requirements.

SECTION II

Technical Assessment & Recommendations

On July 21 and 22, a representative from WAS, Inc., visited the LPF to examine its test equipment and accessories related to the performance of ASTM D 4761, as well as, ASTM D 143, Standard Test Methods for Small Clear Specimens of Timber. During the two-day assessment, the following was conducted:

- Assessed load accuracy of Tinius Olsen Electromatic Test Apparatus, 15,000 kg capacity, serial no. 101333-2 using an ELE/Soil Test PR-100 (4,545 kg capacity) owned and calibrated by WAS, Inc.
- Assessed load accuracy of LPF Bending Test Apparatus with the ELE/Soil Test PR-100 (4,545 kg capacity) owned and calibrated by WAS, Inc.
- Examined current calibration equipment for each test machine.
- Observed the use of the test equipment, accessories, data acquisition, and personnel during the testing of two sizes of lumber (2x4 and 2x6) following ASTM D 4761 test procedures.
- Examined the laboratory equipment necessary to determine moisture content (MC) and specific gravity (SG).
- Examined the outdoor storage facilities.

In general, the personnel are capable of conducting a full testing program. However, there are some minor, yet important, issues that should be addressed before the program is initiated.

A. Tinius Olsen Test Machine

A primary goal of the visit was to assess the capability of the LPF test equipment. Thus, using the WAS calibrated ELE/Soil test PR-100 proving ring each test machine was examined for load accuracy. The results are discussed in section II - A and II - B and presented in Tables 1 and 2.

For the Tinius Olsen test machine, the proving ring was placed below the load head and load was applied continuously until a targeted proving ring division was reached. The goal was to stop the test machine at each targeted proving ring division and read the load. The targeted proving ring divisions were 200, 400, 600, and 800. The machine was stopped as close as possible to each targeted division. When the machine was stopped, the actual proving ring division was documented, as well as the test machine load. The load associated with each proving ring division was recorded from the WAS, Inc. calibration sheets. The results of this assessment are listed in Table 1. The percent difference between the proving ring and the test machine was greater than 1.0% at the 200 division and less than 1.0% at the 400, 600, and 800 division readings. While these readings demonstrate a consistent machine, the low load range was out of acceptable accuracy (K1.0%) according to ASTM D 143. Since this test machine would be used to perform the compression perpendicular-to-grain and shear parallel-to-grain testing, ASTM D 143 calibration procedures, section 23 would apply:

> All apparatus used in obtaining data shall be calibrated at sufficiently frequent intervals to ensure accuracy (Practice E4).

It is my understanding that there is no current documentation illustrating that this Tinius Olsen test machine has been recently calibrated. Therefore, we recommend one of the following as a course of action to ensure load accuracy:

- Arrange to have a qualified professional, such as a Tinius Olsen representative or equivalent, calibrate the test machine and provide the LPF with a certified letter documenting when the machine was calibrated and if any adjustments were made. Keep all calibration records on file for documentation. For example, at WAS, Inc. our bench top Tinius Olsen test machine is calibrated once every year. The cost this year (2004) was $985 US plus $170 US for a calibration certificate.

- The LPF must regularly demonstrate the output accuracy of the test machine to a known calibrated instrument, such as a proving ring. If this recommendation is followed, then any necessary adjustment between the proving ring and the Tinius Olsen output would have to be developed. Keep all calibration records on file for documentation.

B. Bending Test Apparatus

The bending test apparatus is a vertical assembly. The assembly consists of a manual load application (hand-pump), a load head assembly with two adjustable steel rollers (with plates), two adjustable reactions (with steel rollers and plates), one LVDT for deflection measuring, a pressure transducer attached to the manual load pump for load measuring, an output box to display both LVDT and pressure transducer readings, and two lateral supports.

Prior to the testing of any lumber during the technical assessment of the LPF, the load accuracy of the bending test apparatus was assessed using the WAS, Inc. PR-100 proving ring. Targeted proving ring division readings were 100, 200, 300, and 400. Load was manually applied with the hand pump. When the load approached a targeted proving ring division, the reader was signaled by the caller. Once the load was at the approximate proving ring division a reading was called out. The results of the assessment are provided in Table 2. At the 100 division level the percent difference between the bending test equipment and the WAS, Inc. calibrated proving ring was less than 1.0%. However, the differences at the 200, 300, and 400 division levels were 3.44%, 3.51%, and 3.52%, respectively.

Table 1
Assessment of load accuracy for the LPF Tinius Olsen Electromatic, 15,000 kg Capacity Test Machine

Test Run	Targeted Division [1]	Actual Division Read [2]	Tinius Olsen Load (kg)	Proving Ring Load (kg)	Difference
Run 1	200	201	912.5	938	2.79%
Run 2	200	201	925	938	1.41%
Run 3	200	201	925	938	1.41%
Average					**1.87%**
Run 1	400	401	1837.5	1845	0.41%
Run 2	400	400	1837.5	1840	0.13%
Run 3	400	400	1837.5	1840	0.13%
Average					**0.22%**
Run 1	600	600	2750	2747	0.11%
Run 2	600	598	2737.5	2738	0.09%
Run 3	600	599	2750	2743	0.25%
Average					**0.15%**
Run 1	800	795	3625	3632	0.19%
Run 2	800	796	3625	3636	0.30%
Run 3	800	802	3650	3659	0.25%
Average					**0.25%**

[1] Targeted division - The division on the PR-100 proving ring that was targeted for reading.

[2] Actual division read - For each run, the test machine was stopped as close as possible to each targeted division. However, some readings were either slightly above or below the target. The appropriate proving ring load is provided for each actual division read.

Table 2
Assessment of load accuracy for the LPF Bending Test Apparatus

Test Run	Division Read	Test Equipment Load	Proving Ring Load (kg)	Difference
Run 1	100	489	480	1.84%
Run 2	100	476	480	0.84%
Run 3	100	482	480	0.41%
Run 4	100	482	480	0.41%
Average				**1.87%**
Run 1	200	964	934	3.11%
Run 2	200	969	934	3.61%
Run 3	200	971	934	3.81%
Run 4	200	965	934	3.21%
Average				**3.44%**
Run 1	300	1436	1387	3.41%
Run 2	300	1439	1387	3.61%
Run 3	300	1439	1387	3.61%
Run 4	300	1436	1387	3.41%
Average				**3.51%**
Run 1	400	1906	1840	3.46%
Run 2	400	1908	1840	3.56%
Run 3	400	1907	1840	3.51%
Run 4	400	1908	1840	3.56%
Average				**3.52%**

According to ASTM D 4761, section 8.3 Accuracy, the following must apply for the force measuring apparatus:

> 8.3.2 The force-measuring apparatus shall be such as to permit load measurements with an error not to exceed K 1.0% of the load for loads greater than or equal to 1000 lbf (4450 N). For loads smaller than 1000 1bf, the error shall not exceed K 10 lbf (45 N).

While the load readings from the bending test equipment were acceptable at the low load range, they were consistently out of range at the higher load levels. Therefore, we would recommend one of the following as a course of action to ensure load accuracy:

- If the manual loading and current pressure transducers are utilized, then we recommend that a qualified professional calibrate the pressure transducer. Additionally, daily calibration with a proving ring should be conducted during each day of testing to verify and document proper load accuracy. Keep all calibration records on file for documentation.

- Purchase a new load cell which should be certified and calibrated upon purchase. Properly incorporate the new load cell as instructed by the manufacturer into the bending test apparatus. Document during each day of testing that the load cell is providing appropriate load accuracy. Keep all calibration records on file for documentation.

C. Proving Ring

The LPF currently owns two proving rings; however, it is our understanding that there is no calibration documentation for either proving ring. Therefore, we make the following recommendation:

- Purchase a new proving ring from a certified proving ring manufacturer, such as ELE Soil Test.

- Send the current proving ring(s) to WAS, Inc. for calibration.

SECTION III

Conducting ASTM D 4761 & Recommendations

Since ASTM D 4761 will be employed to perform the testing at the LPF, then the following sections apply to the assessment conducted by WAS, Inc. Based on the technical assessment of the bending test apparatus, recommendations are provided per each ASTM D 4761.

A. ASTM D 4761 - 8.1 Test Machine

The bending test apparatus at the LPF meets the ASTM definition of an acceptable test machine; except that the force measuring apparatus has not been calibrated to the accuracy requirements of section 8.3.2 in ASTM D 4761 (see II - B for recommendations regarding calibrated equipment).

B. ASTM D 4761 - 8.1.1 Load & Support Apparatus

The bending test load and support apparatus meets the description in ASTM. The bearing plates are wider than the test specimens and they do not exceed 8 in (20 cm) in length. For example, the bearing plates used at WAS, Inc. are 5 in wide x 4 in long x ½ in wide on the supports and 3 in wide x 4 in long x ½ in wide on the third point load head assembly.

Rollers are also part of the LPF bending test apparatus. It is not required that the plates be fixed to the rollers, however, the rollers used by WAS, Inc. are fixed, therefore, we suggest the following recommendation:

- Attach the plates permanently to each roller so that plates do not fall to the floor after each board failure.

C. ASTM D 4761 - 8.1.2 Loading Configuration

According to this section, the simply supported test specimens must be subjected to equal transverse concentrated loads spaced at equal distances from the supports. For testing 2x4's, 2x6's, and 2x8's, this requires the following test spans and third point spans:

Nominal Size	Actual Test Span	Actual Third Point Test Span
2 in x4 in x8 ft	60 in. or 151 cm	20 in. or 50.3 cm
2in x6in x10 ft	93 in. or 234 cm	31 in. or 78 cm
2 in x8 in x12 ft	123 in. or 310 cm	41 in. or 103.3 cm

The LPF bending test apparatus can currently attain the 2x6 and 2x8 test spans and third point test spans, but for a 2x4 test piece.

- Adjust LPF bending test apparatus so that standard test spans listed above can be used. Additionally, ensure that the apparatus is centered, plum, all connections are securely tightened, and loading configuration is symmetrical about the loading ram.

D. ASTM D 4761 - 8.1.3 Lateral Supports

Lateral supports are necessary to restrict the specimen from lateral deflection. Additionally, the lateral supports should allow movement of the specimen in the direction of load application, but they should allow minimal frictional movement.

While testing several boards during the technical assessment, the current lateral supports failed to provide the necessary lateral support according to ASTM D 4761.

- Modify the lateral supports so that they are securely fastened below each board tested during the entire testing program. As stated in section 8.1.3 of ASTM Standard D 4761, These supports shall allow movement of the specimen in the direction of load application and have minimal frictional restraint. The LPF may want to consider Teflon faces or rollers as frictionless surfaces since warp may be common in the lumber tested.

E. ASTM D4761 - 8.2 Deflection Measuring Apparatus

During the testing of each board, it is imperative that the deflection be accurately measured to calculate modulus of elasticity (MOE). Deflection may be measured by the displacement of the loading head of the test machine or by an extraneous component suitable for measuring deflection.

Currently the LPF utilizes an LVDT for measuring deflection during testing. This is considered a suitable extraneous component, however, calibration will be required for an LVDT. Calibration would also be required for monitoring deflection by load head movement. During the technical assessment, two (2) methods were employed to examine the LPF LVDT accuracy. First, a rod 75mm in length was used several times to gage the output deflection, and second, a micrometer was used to gage output deflection. The results are listed below:

Table 3
Assessment of LPF LVDT Using a 75 mm Rod.

LVDT Reading	% Difference
72.7 mm	3.07
73.6 mm	1.87
73.8 mm	1.60
74.4 mm	0.80
74.6 mm	0.56
76.2 mm	1.60
75.0 mm	0.0
75.0 mm	0.0

Table 4
Assessment of LPF LVDT Using a Micrometer.

Micrometer	LVDT Reading	% Difference
25.3 mm	24.3 mm	3.95

28.4 mm	28.0 mm	1.40
20.1 mm	19.1 mm	4.98
24.5 mm	24.0 mm	2.08
27.4 mm	26.7 mm	2.55

Several of the readings for the LPF LVDT were greater than 2.0% in variation. Additionally, it is my understanding that this LVDT has not been calibrated. Discussed in section 8.3 accuracy, of ASTM D 4761 the deflection measuring apparatus shall not have an error greater than K 2.0%.

- Option 1: If the current LVDT will be used during the testing, then it should be calibrated by a qualified professional prior to the initiation of the test program.

- Option 2: Purchase an upgraded LVDT prior to the initiation of the test program. The current LVDT used by the LPF was manufactured by Celesco. Model # PTI-MA is equivalent to the current LPF LVDT and would cost approximately $374.00 US - $398.00 US.

- Option 3: Modify the bending apparatus to monitor load head deflection. This option would require computer software and an aluminum bar for calibration purposes. Additionally, the load head displacement would have to be monitored using a suitable device. For example, the WAS, Inc. bending test machine monitors load head deflection using a ball screw encoder. Prior to each four-hour shift of testing, we use an aluminum bar and our computer software to calibrate the machine. All daily calibration records are kept and filed for documentation.

F. ASTM D4761 - 8.3 Accuracy

The accuracy for load and deflection were already discussed. For the bending test, load accuracy was discussed within the body of text provided in section II - B of this report. Deflection accuracy was discussed in section III - E of this report. See these sections for discussions and recommendations regarding accuracy.

For reporting purposes, ASTM D 4761 requires a record of the calibration procedure and frequency.

- Keep a record of all calibrated equipment and keep a daily record of the load measuring apparatus and deflection measuring apparatus for bending test machine.

G. ASTM D 4761 - 9 Test Specimen

Covered under this section of the standard are the requirements for each test specimen such as cross section, length, and conditioning. The cross sections to be tested for this program are nominal 2x4, 2x6, and 2x8 which apply to ASTM D 4761. The length of the test specimens shall be such that the spans to depth ratios range from 17 times to 21 times the depth of the test specimen.

- For typical ALSC test programs a span-to-depth ratio of 17:1 is commonly used. The spans provided in section III - C of this report are based on a 17:1 span to depth ratio. We recommend that these spans and third point spans be employed for each size. If they are not and a different span to depth ratio is employed then ASTM D 2915 should be referenced for variations in the apparent modulus of elasticity.

The test specimens may be tested as produced or conditioned. Temperatures less than 7EC or greater than 32EC must be reported at the time of testing. The analysis of the test data will be adjusted for MC. All data is ultimately adjusted to 15%. MC Covered storage is available at the LPF, but it may not prevent wetting of lumber during rain.

- All lumber should be conditioned to approximately 12% to 19% MC, targeting 15%. The material may be stored outdoors; however, it should be protected from wetting. If the lumber is stored outdoors at the LPF during the test program, then ensure dry storage conditions by including stickering. This promotes drying if the lumber should happen to get wet.

H. ASTM D 4761 - 10 Procedure

The procedure for each bending test consists of documenting the specimen dimensions (length, width, and depth) to the nearest 0.04 in (1mm). The test specimen shall be located within the test span without bias regarding defects and the tension edge shall be randomly selected. The speed of testing shall be at a rate so that failures can be reached in approximately 1 min. The failure should not occur in less than 10 seconds and should occur before 10 minutes. A load of application of 3 in per minute will generally result in a bending failure between the standard time limit. Load and deflection data shall be recorded to that described in section III - E of this report. The maximum load shall be recorded to determine modulus of rupture (MOR). Lastly, the failure must be recorded according to Table X1.1 in ASTM D 4761.

Several 2x4 and 2x6 lumber specimens were tested during the technical assessment of the LPF and its personnel. The lab is currently performing the procedure described in Section 10 of ASTM D 4761 using a manual application of load, a pressure transducer for load output and an LVDT for deflection output. Each piece was tested in approximately 3 to 5 minutes. Load and deflection data for each piece tested were first recorded at a slow rate (approximately 1-2 minutes). Once a representative set of data was recorded, the rate of application was increased until failure occurred (approximately 1-2 minutes). Six example load deflection graphs (three 2x4 and three 2x6 samples) are provided in Appendix I. The data are fairly consistent for the manual operation, but occasional data points are clearly out of the linear region of the data. This may be due to the inaccuracy of LVDT, anomalies in the manual load apparatus, or a combination of both. See section III - F of this report regarding accuracy recommendations if any.

Based on the technical assessment of the LPF and its personnel, the current procedure for data acquisition requires at least two to three persons, one person to record failure, and one person to cut broken boards into samples for additional analyses and testing. If this process is utilized for the test program, then the recommendations which have been provided thus far for the bending apparatus should be implemented and the testing would meet the requirements of ASTM D 4761. However, based on the current bending test apparatus and data acquisition procedures, the test program would be extremely labor intensive and meeting the targeted completion of the program in eight to 12 months, prescribed by Chemonics, may not be possible.

Therefore, we are providing the following recommendation and options for more efficient means of data acquisition which will inevitably reduce the personnel required to perform the testing.

Recommendations for electronic data acquisition include:

- Option 1: *Data logger*. A data logger such as a Campbell 23X, can be used to collect load and deflection data from a load transducer, load cell, LVDT, or any device used to monitor load head deflection. The data can be collected in DOS format using a computer. A professional, experienced in instrumentation, would have to be contacted for proper set-up of the equipment. The load and deflection data for each piece of tested lumber could then be imported into a spreadsheet program (i.e., Lotus or Excel). Once the data was imported, a load/deflection curve could be developed. The linear portion of the curve could be used to calculate MOE and the maximum load could be used to calculate MOR.

- Option 2: *Computer Software*. A specialist experienced in software production would need to be hired for this option or, currently available software would need to be purchased. Usually, a computer operating Windows can be easily utilized to operate any testing software. The software must be capable of load and deflection data acquisition in order to calculate MOE and MOR. For MOE, the linear portion of the load-deflection data must be used and for MOR, the maximum load must be recorded. The computer software must be capable of recording and/or calculating the following:
    - Specimen width and thickness.
    - Load-deflection graphs for determination of MOE.
    - Save record of graph.
    - Maximum load for determination of MOR.
    - Calculate MOE (for third point loading configuration).
    - Calculate MOR (for third point loading configuration).

Option 1 or 2 should only necessitate 2 or 3 persons to perform the test. At WAS, Inc., only 2 personnel are required to perform the bending test, as well as determining GQI, cutting and weighing of MC/SG samples per 8 hour shift. We have conducted in-grade testing programs for over 10 years resulting in an efficient program.

I. Purchasing or Building a Bending Test Apparatus

Another option which has not been discussed is the purchasing or building of a bending test apparatus. This option would not require the modification of the current LPF bending test machine. There are a variety of companies which specialize in selling new and used bending test apparatus. We suggest any of the following:

- Tinius Olsen
- Instron
- MTS Systems
- Testing Machines, Inc.

We recommend that a bending test machine of at least 10,000 lbs. be used for performing the in-grade test program. The cost to purchase a bending test apparatus could range between $20,000.00 US and $50,000.00 US which may or may not include the software. These costs do not include set-up or delivery costs of the bending test apparatus. They would be dependent upon the manufacturer. We recommend contacting the companies for specific individual quotes. "Design of a Hydraulic Bending Machine", FPL-GTR-148 by Steve Hankel and Marshall Begal. Alternatively, this paper can also be used to have a custom bending test apparatus built. The cost for a custom built machine is unknown since a quote would have to be provided by an individual or company.

J. ASTM D 4761 - 11 Report

Discussed in this section of ASTM D 4761 are a multitude of requirements for in-grade testing of lumber. The topics include several of the issues which have been addressed in this report. It has been decided by Chemonics and RRA that WAS will prepare a second report that would outline the logistics of managing and reporting an in-grade testing program on a daily basis. This report will be submitted to RRA in the fall of 2004 after the LPF has implemented the recommendations of this report and prior to the commencement of any testing.

SECTION IV

Miscellaneous Recommendations and Conclusions

In addition to the recommendations provided thus far, WAS suggests that the LPF implement additional modifications for performing an in-grade test program. They are: determination of moisture content and specific gravity, and the LPF laboratory lay-out.

A. Determination of Moisture Content & Specific Gravity

For every piece of lumber tested and each compression perpendicular-to-grain and shear parallel-to-grain test, the MC and SG must be determined. Currently the LPF is equipped to determine MC and SG per ASTM D 4442, Standard Test Methods for Direct Moisture Content Measurement of Wood and Wood-Based Material, and ASTM D 2395, Standard Test Methods for Specific Gravity of Wood and Wood-Based Material. Each sample used to determine MC and SG must be weighed immediately after the test.

The oven dry method is recommended for each analysis. This requires an oven which must be capable of maintaining a temperature of 103K2EC throughout the drying. For determination of SG, we recommend using the volume by water immersion method (Method B). To determine MC, each test piece must first be weighed immediately after completion of a test and then dried to the oven dry weight. To determine SG, the sample should then be dipped into paraffin wax and immersed in water to determine the oven dry volume. Oven dry volume must be determined immediately following documentation of the oven dry weight. The LPF, at the time of this assessment, did not have any paraffin wax for the water immersion method. Additionally, it is our understanding that a new oven may need to be purchased for the MC/SG analysis. We recommend that paraffin wax be purchased prior to the commencement of the testing program.

In order to perform the ASTM D 4442 and ASTM D 2395 MC/SG analysis, the following equipment is necessary (estimated costs and companies are provided):

Oven	Gravity Convection; (e.g., Thomas Scientific, 800-345-2100, or Cole-Parmer, 800-323-4340) Cost: $1,200.00 US - $1,700.00 US (must maintain temperature of 103°C±2°C).
Paraffin Wax	Paraplast tissue embedding medium (e.g., Thomas Scientific, 800-345-2100, or Cole-Parmer, 800-323-4340) Cost: $40.00 US, package of 8 bags.
Hot Plate	Capable of reaching + 56°C to melt paraffin wax (e.g., Thomas Scientific, 800-345-2100, or Cole-Parmer, 800-323-4340). Cost: $100.00 US - $150.00 US

B. LPF Floor Plan

During the technical assessment, it was observed that the equipment necessary to perform the test program was located a large distances from each other. We recommend that the equipment be positioned closer together to ensure efficient use of time during the test program. As an example, we have attached an illustration of the WAS, Inc. floor plan (Appendix III). We do not necessarily recommend that this floor plan be imitated by the LPF, but it can be used as a guide to reassemble their equipment for improved testing efficiency.

C. Conclusions

A two-day technical assessment of the LPF was conducted by WAS in the company of Chemonics and RRA. Based on that assessment, this report was prepared and recommendations were provided for the LPF in preparation for implementing an in-grade testing program of two species of Columbian pine.